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Use of Surface Features of Quartz Grains as Indicators of Various Modern Sedimentary Environments Along the Eastern Coastal Plain of the Red Sea, Saudi Arabia

Abstract: The study was made in an attempt to differentiate between various modern environments using the natural surface features observed in quartz grains. Quartz grains from a number of recent environments (beach and nearshore, tidal flat and sabkha, coastal and inland dunes) were examined from Jeddah region.

Different information is available concerning occurrence and distribution of chemical and mechanical surface features and their relationship to the different environments.

Examination of quartz grain surface textures using the scanning electron microscope indicates that the transport and deposition in certain environments can be recognized by characteristic features.

الملامح السطحية لحبيبات الكوارتز الرملية كأدلة لبيئات الارساب
الحديثة على طول السهل الساحلى الشرقى
للبحر الأحمر ، منطقة جدة ، المملكة العربية السعودية
أمين مصطفى غيث

المستخلص: تمت هذه الدراسة فى محاولة للتفرقة بين بيئات الترسيب الحديثة باستخدام ملامح السطح الطبيعية لحبيبات الكوارتز. واعتمدت الدراسة على فحص حبيبات الكوارتز لعدد من البيئات الحديثة التى شملت كل من البيئة الساحليه والقريبة من الساحل، المسطحات المدية والسبخات ، والكثبان الرملية الساحلية والداخلية لمنطقة جدة باستخدام الميكروسكوب الالكترونى الماسح.

وقد دل فحص الأنسجة السطحية لحبيبات الكوارتز على ان لكل من عملية النقل والارساب لحبيبات الكوارتز فى بيئة معينة ملامح مميزة.

هذا وقد أمكن التوصل الى معلومات مفيدة عن شكل وتوزيع كل من ملامح السطح الميكانيكية والكيميائية وعلاقتها بالبيئات الترسيبية الحديثة.

Introduction

The eastern coastal plain of the Red Sea is bounded by the hills and mountains of the Arabian shield that provide much detritus which moves across the coastal plain to the sea. On the other hand, the coastal plain is characterized by coral reef accumulation; therefore, the production of reefal sediments and carbonates is expectedly high. In fact, the coastal plain is very important for tidal flats and sabkhas, and coastal and inland dunes. With such a variety of deposition, this area provides a natural laboratory for arid coastal and nearshore sedimentation, where the respective processes, deposits and environment can be observed and studied.

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Various studies have related the surface textures of modern quartz sand grains to the sedimentary environments. These studies were based on the assumption that the agent of sedimentation leaves certain characteristic features on the grain surfaces. Therefore, the recognition of these surface features helps to deduce the agents of transport and depositional environment. The recent use of the scanning electron microscope to study surface features of detrital quartz sand grains has provided a new source of information about the depositional history of sands (Krinsley and Takahashi, 1962; Biederman, 1962; Krinsley and Funnell, 1965; Margolis, 1968; Krinsley and Donhame, 1968; Nordstrom and Margolis, 1972; Blackwelder and Pilkey, 1972; Krinsley, *et al.* 1973; Krinsley and Doornkamps, 1973; Margolis and Krinsley, 1974; Subramanian, 1975; Ly, 1978; Manker and Ponder, 1978). Review of all these publications reveal differences in the attribution of the observed textures to the various environments and in the interpretation of their genesis.

Al-Saleh and Khalaf (1982) found relict and recent mechanical surface features in recent desert sand grains while those from sabkhas had a

dominance of chemical surface features. El-Fishawi and Molnar (1984); El-Askary and Frihy (1984); Frihy and Stanley (1987) and Abd Alla (1991) distinguished sands from several subaerial and subaqueous recent environments as well as from Holocene subsurface core samples in the Nile Delta coastal region using the characteristic quartz grain surface features.

Samples and procedures:

The samples used in this study are part of a collection obtained for a regional environmental study on the eastern Red Sea coastal area (Gheith and Abou Ouf, 1996 and Gheith, 1999). Ten representative samples have been selected from recent subenvironments (beach and nearshore, tidal flat and sabkhas, and coastal and inland sand dunes) in the Jeddah coastal region (Table 1, Fig. 1).

Table (1): Location of the samples studied and their environments of deposition

S.no.	Location	Environment
1	Rabigh coast	Beach zone
2	" "	Nearshore zone
3	Shuayba lagoon	Tidal flat and sabkha
4	" "	" " "
5	" "	" " "
6	" "	" " "
7	Shuayba coast	Coastal sand dune
8	Southern corniche	" " "
9	Jeddah-Mekkah road	Inland sand dune
10	" "	" " " "

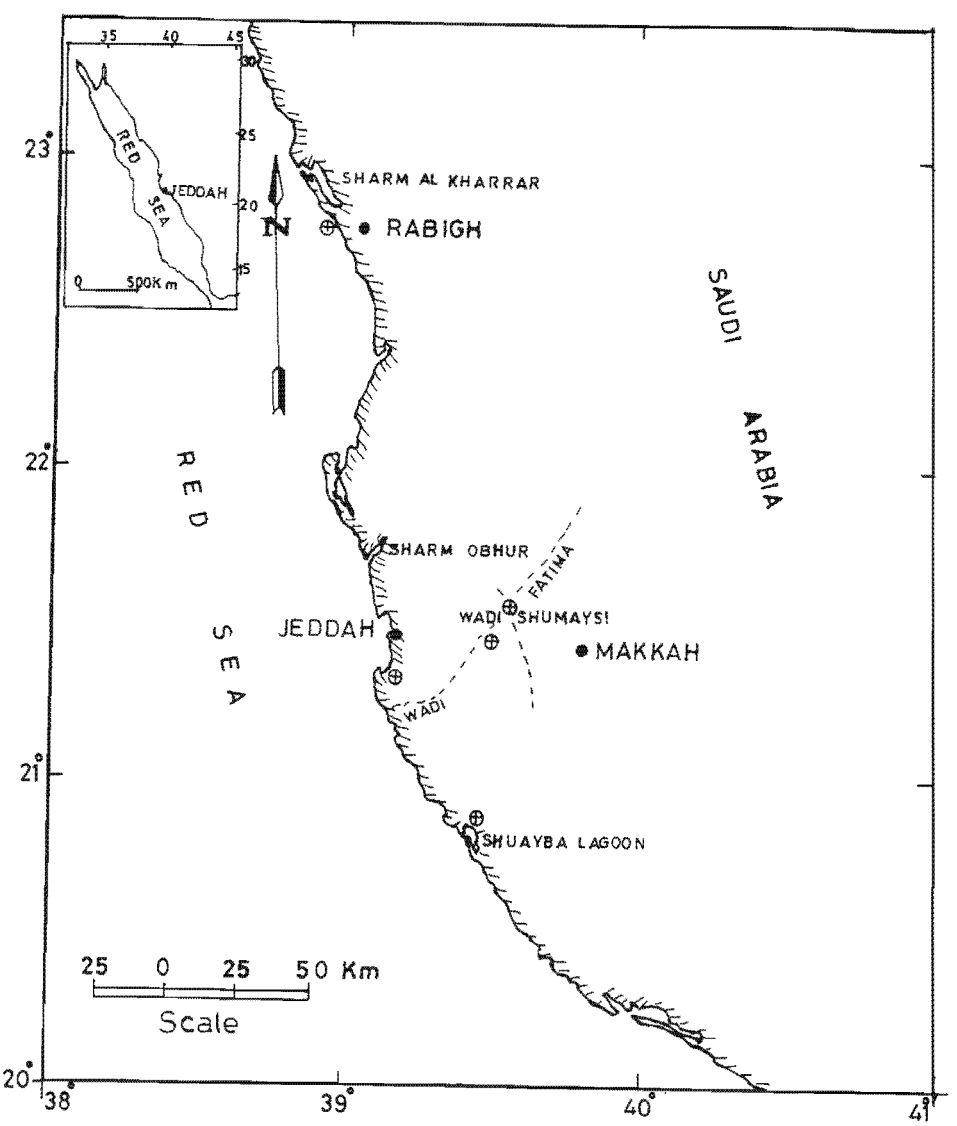


Fig. 1 Map showing location of collected samples (⊕)

The procedures used for cleaning quartz sand grains for SEM examination are those described by Krinsley and Doornkamp (1973). Each sample was placed in concentrated HCL for ten minutes, then washed with distilled water. With the aid of a binocular microscope, 15 grains were selected at random from each sample and mounted on SEM stubs with silver paint and then coated with gold under a vacuum evaporator. Diagnostic features were identified and photographed with a Jeol-50 A scanning electron microscope at King Abdulaziz University. Photographs of the grain surface were taken at various magnifications.

Results and Discussion

Investigation of quartz surface features from the various recent environments of Saudi Arabia proved that the quartz grains of each environment are characterized by an abundance of certain surface features produced by the action of chemical and mechanical agents. Occurrence, distribution and overlapping of the surface features are used to differentiate between the different environments.

Beach and Nearshore Sands:

Samples studied have been collected through shore profiles normal to the beach at Rabigh coast, north of Jeddah area. The surface sand grain features are mainly dominated by mechanical V-shaped pits (Fig. 2A), upturned plates with meandering grooves (Fig. 2B) and oriented fractures (Fig. 2C). Sand grains from this environment have distinct surface features that are caused by the mechanical abrasion in the surf zone during sand movement along high turblent energy beach.

Most of the aeolian sand surface features have mechanical V-shaped pits, upturned plates and rounded or curved pitted grooves too. These features proved that some of the beach sediments at Rabigh coast were transported by wind and deposited under the influences of waves and tidal currents to form beach sediments (Gheith, 2000). However, mechanical V-shaped and grooves were used as an indication of proximity to a marine environment (Baker Jr., 1976).

Tidal Flat and Sabkha Sands:

Samples were collected from the supratidal sabkha deposits of the Shuayba lagoon, south of Jeddah region. The Shuayba area suffers from hard ecological conditions and is characterized by an intensive dry climate, with only one of the two

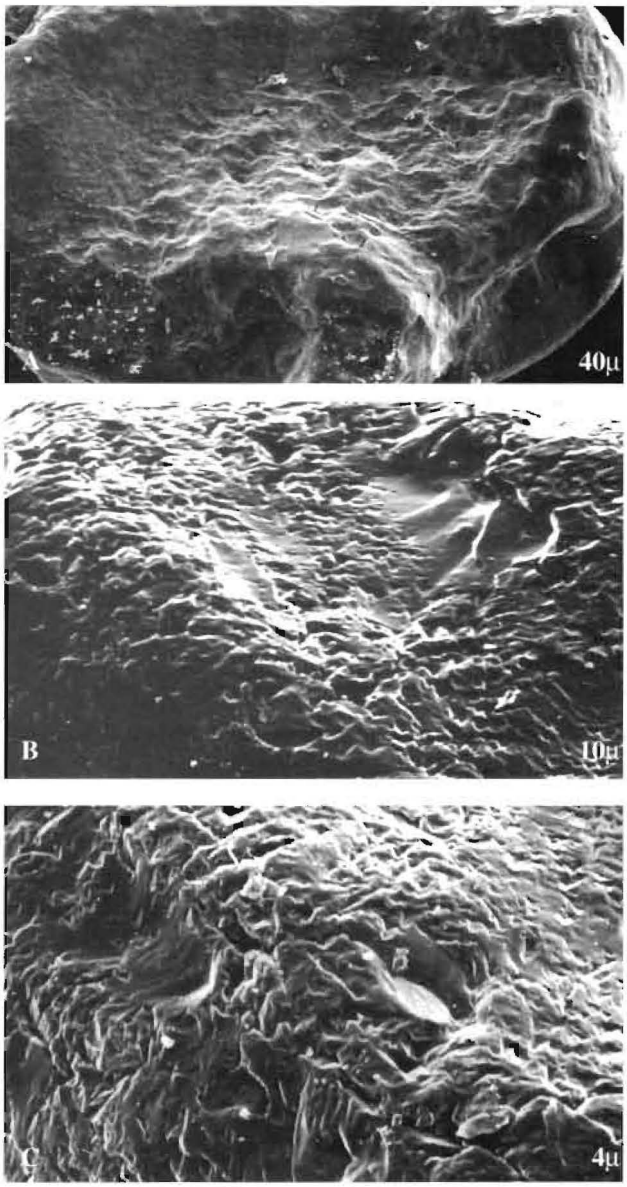


Fig. 2 Surface textures on quartz sand grains (SEM) of the beach sediments,

(A) Oriented mechanical V-shaped pits on quartx grain

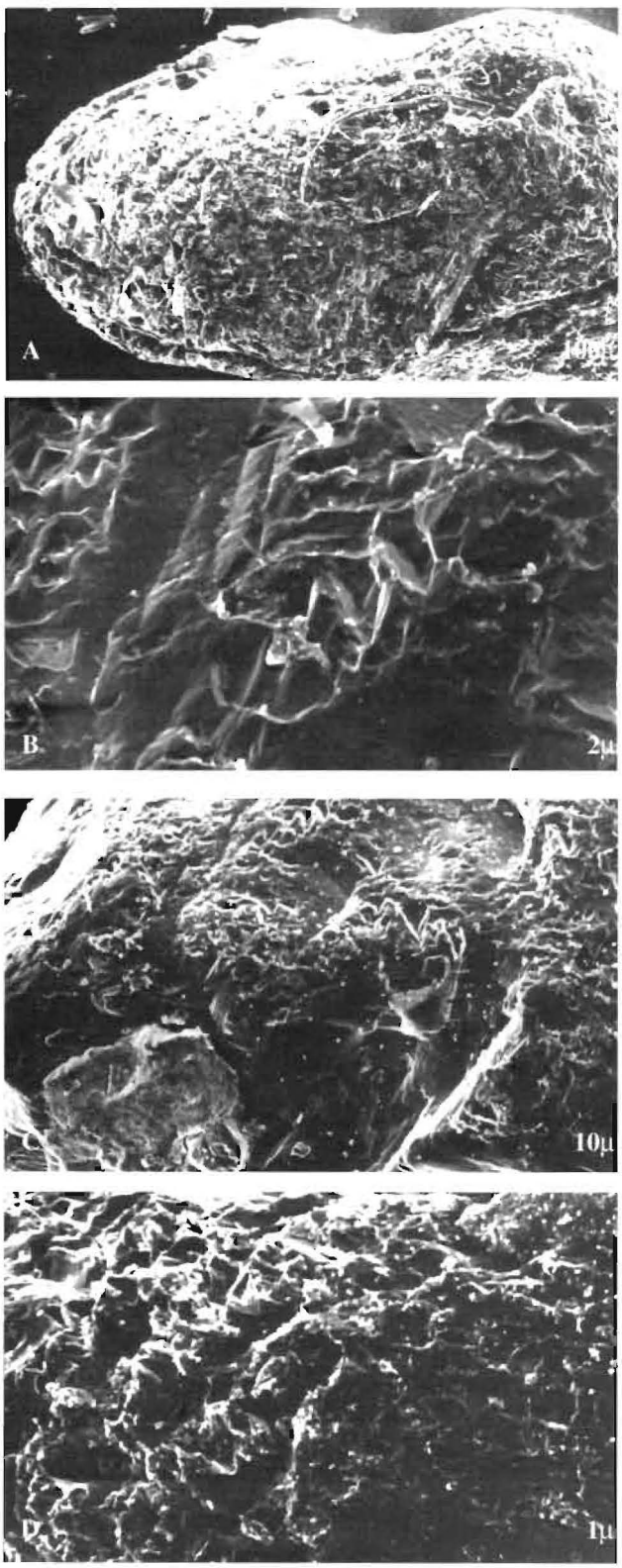
(B) Upturned plates with meandering groves

(C) Oriented fractures

connected wadies flowing over a short period in a year. The southern and the eastern parts of the lagoon are bounded by extensive tidal flats and upper supratidal sabkhas. The sabkha sediments are enriched with cerithid gastropods, coral fragments, red algae and small amounts of terrigenous components. Minerallogically, these sediments are composed of carbonate minerals (aragonite, Mg-calcite and dolomite), evaporites (gypsum and halite) and detrital quartz and feldspar (Gheith, 1999).

The surface features observed in this environments are shown in Fig. (3). They are characterized by the predominance of chemical features which are generally developed by solution

(etching) and precipitation in the recent near surface diagenetic environment. The chemical features include: rounded quartz grains that have highly suffered chemical action (Fig. 3A), triangular etch pits (Fig. 3B), concentric triangular etch pits (Fig. 3C), irregular solution pits (Fig. 3D), striations and deep grooves (Fig. 3E, G), silica precipitation and irregular plates (Fig. 3F) and cavity fillings (Fig. 3H).



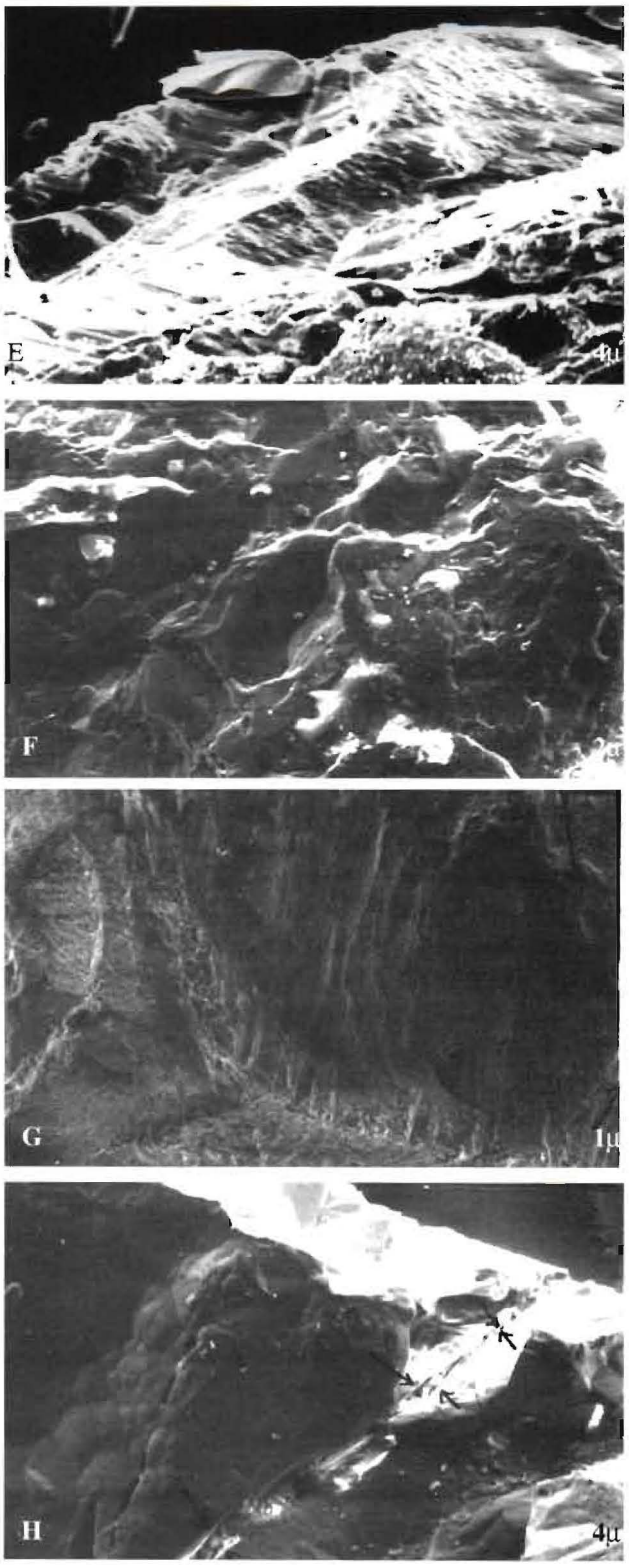
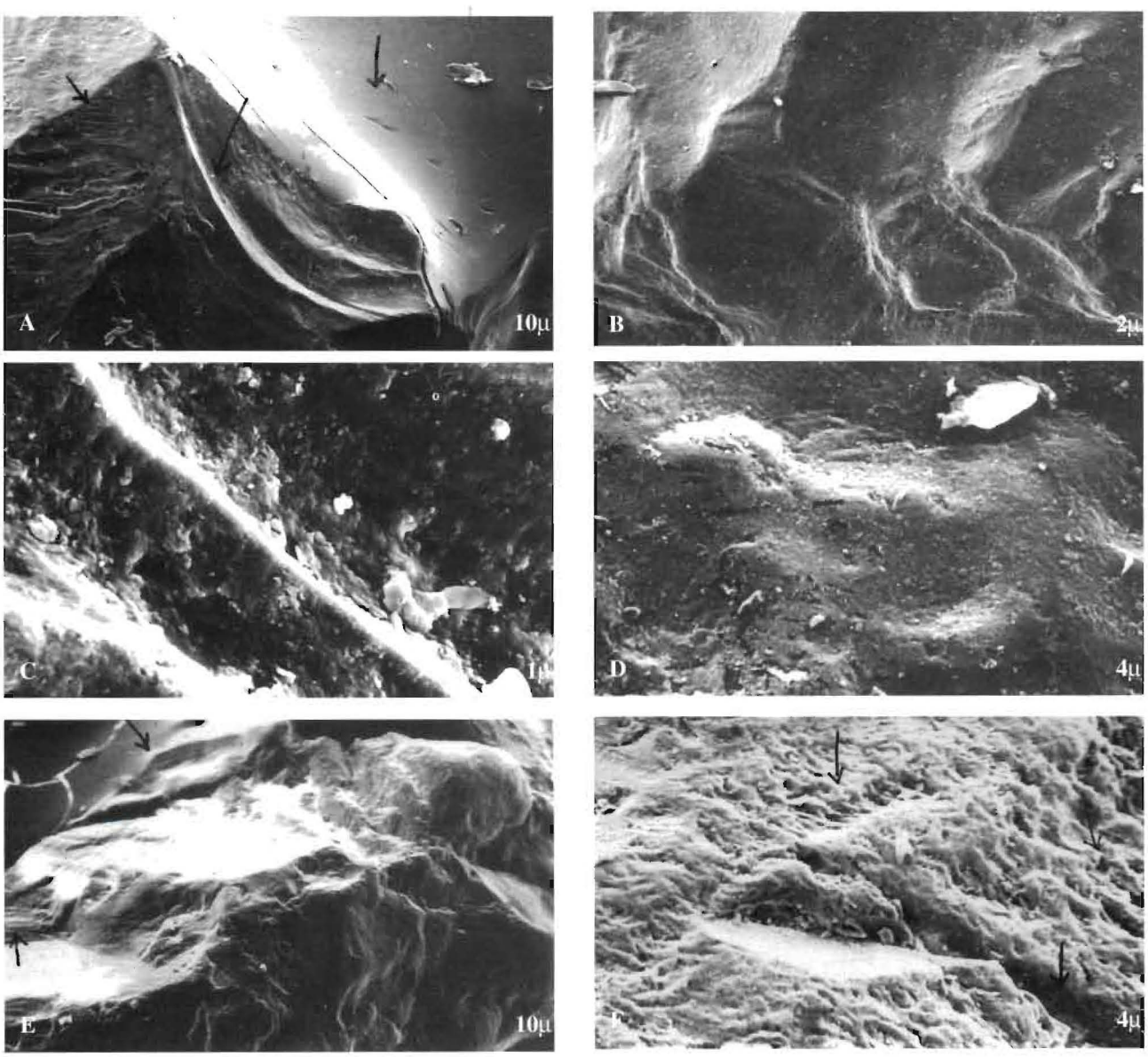


Fig. 3. Surface textures on quartz sand grains (SEM) from coastal tidal flat sabkha and deposits,
(A) Subrounded quartz grain with highly chemical features
(B) Oriented triangular etching pit,
(C) Large concentric triangular etching pits
(D) Irregular solution pits
(E) Striation
(F) Upturned plates with silica precipitation,
(G) Deep etching grooves
(H) Cavity filling with irregular breakage pattern

The most diagnostic features of sand grains of this environment are the triangular etch depressions. Chemical etching along planes of weakness (cleavage or fracture) occurs extensively in the sand grains of this environment and thus V-shaped and oriented pits are usually much denser than those found in the grains of normal subaqueous environments. Factors controlling the predominance of chemical features in such sabkha and tidal flat deposits include evaporation which characterizes the arid areas and the abundance of evaporite which increases pH (Al-Saleh and Khalaf, 1980).

Coastal Dune Sands:

Samples studied have been collected from the Shuayba coast and the southern Corniche of Jeddah. The quartz grains appear rounded. The grain surface features observed reflect both mechanical and chemical features. The mechanical features include: conchoidal fracture with smooth surface due to later silica precipitation (Fig. 4A) and stepped cleavage planes (Fig. 4B). The most characteristic chemical features are the precipitation of silica as incipient quartz overgrowth over the fracture planes (Fig. 4C), deposition and solution of silica (Fig. 4D), striations and conchoidal fractures with irregular breakage patterns (Fig. 4E), precipitation of silica in the form of upturned plates (Fig. 4F), and etching of silica and formation of deep haloes (Fig. 4G) or solution of the precipitation of silica on the broken cleavage plates (Fig. 4H). The relict and recent mechanical features in the coastal dune sands are inherited in the wind transported grains, whereas the chemical features are produced by the later action of the sprayed and infiltrated sea water.



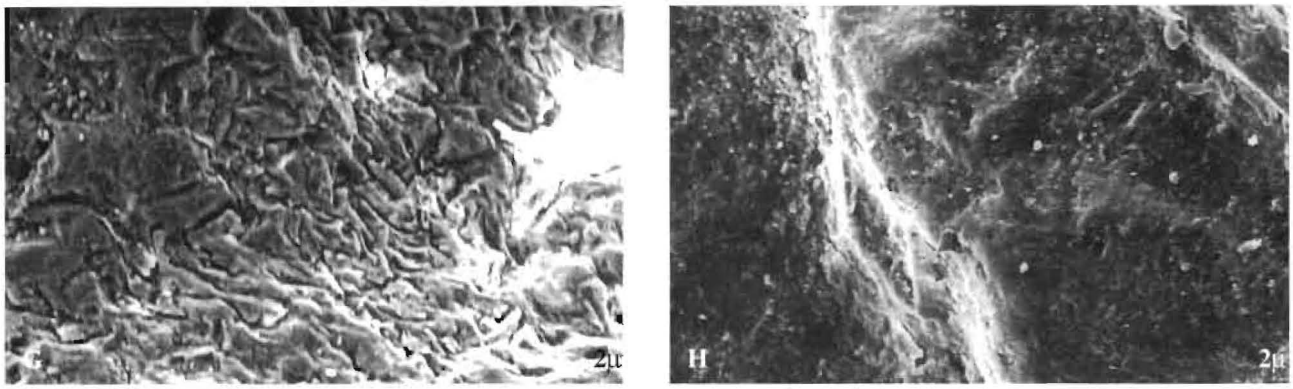


Fig. 4. Surface textures on quartz sand grains (SEM) from coastal sand dunes,
(A) Conchoidal fracture with silica precipitation
(B) Stepped cleavage planes
(C) Silica precipitation as incipient quartz overgrowth on the cleavage planes
(D) Deposition and solution of silica
(E) Conchoidal feature with irregular breakage patterns
(F) Silica precipitation in the form of upturned plates
(G) Solution of silica and formation of deep haloes
(H) Solution and precipitation on the broken cleavage plates

Inland Dune Sands:

The samples have been collected from a group of barchan dunes accumulated near the Jeddah-Mekkah highway. The quartz grains are generally rounded and characterized by smooth dull surfaces due to the evaporation of pore-water filling and the consequent silica precipitation on the surfaces of the mechanical upturned plates (Fig. 5A). The mechanical pits scattered all over the grains were developed during transportation of the grains in the aeolian environment. They show an abundance of mechanical V-shaped pits (Fig. 5B) and chemically etched pits and grooves (Fig. 5C).

Wind abrasion leads to impacts between grains which produce upturned plates on the fractured portions. Solution and precipitation tend to modify the plates and produce rolling topography characteristic of a hot desert environment. Baker, Jr. (1976) suggested that irregular cracks appear to be a good indication of interior desert environments.

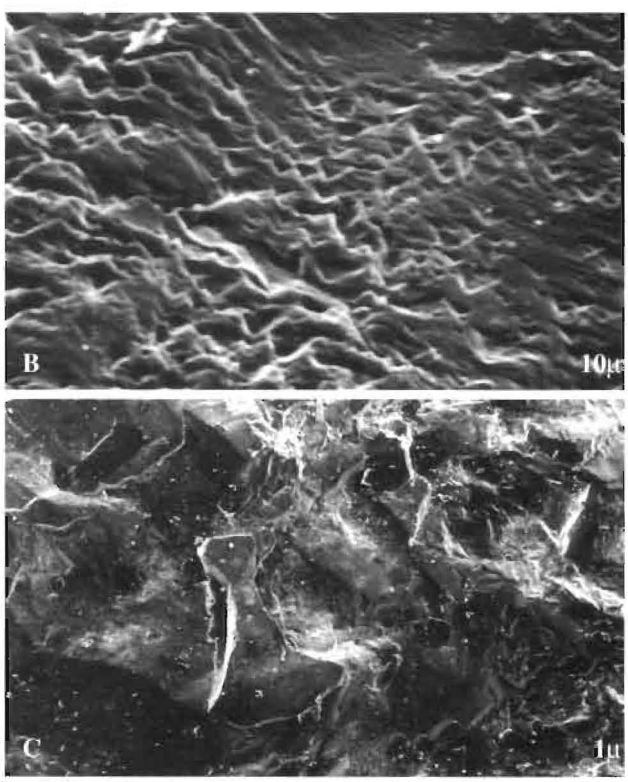
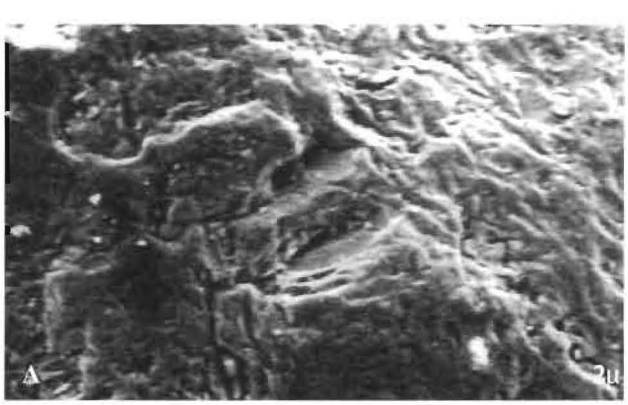


Fig. 5 Surface textures on quartz sand grains (SEM) of the beach sediments,
(A) Oriented mechanical V-shaped pits on quartx grain
(B) Upturned plates with meandering groves
(C) Oriented fractures



From the study of relative frequency distribution of various surface features recorded on the quartz grains of the different studied environments (Table 2), it can be noticed that mechanical features are dominant in beach and desert dune sands, whereas chemical features are mostly confined to the tidal flat, sabkha and coastal dune sands. However, other surface features are recorded in addition to the main characteristic ones.

Table (2): Frequency distribution of mechanical and chemical surface features on quartz sand grains of the different modern environments.

Surface features	Environment	Coastal environments			Inland dune sands
		Beach and nearshore sands	Tidal flats and sabkha sands	Coastal dune sands	
Mechanical V-shaped	Mechanical features	++++	-	-	++++
Conchoidal fracture		++	-	++	+
Upturned plates		++	-	-	++
Striation and deep grooves		++	++	-	++
Stepped cleavage planes		-	-	++	-
Triangular etch pits	Chemical features	-	++++	-	-
Silica precipitation		-	++++	++++	++++
Crystal overgrowth		-	-	++	-
Deep grooves		-	++	++	++

++++Dominant ++Common +Rare -Absent

Conclusions

The quartz grain surface features of ten sand samples collected from coastal and desert areas of Jeddah region were examined using the scanning electron microscope. The study shows the existence of several surface features that reflect the effect of chemical and mechanical action.

The surface textures of quartz sand grains from sabkha and tidal flat environments are characterized by strong chemical action with abundance of etch pits. Chemical surface features of sabkha sand are significant and appear diagnostic of low energy subaqueous sedimentation, while quartz grains from beach and nearshore subenvironments are characterized by mechanical V-shaped pits with minor curved grooves and conchoidal breakage patterns. These features are produced by the turblent aqueous high energy environment. It can be concluded that each type of environment studied is characterized by certain distinctive features.

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